A New Cross-domain QoE Guarantee Method Based on Isomorphism Flow in Internet of Things

Zaijian Wang, Chen Chen, Xinheng Wang, *Member IEEE*

Abstract—**This paper investigates the issue of Quality of Experience (QoE) for multimedia services in Internet of Things (IoT), introduces a new concept of "Isomorphism Flow"(iFlow) for multimedia traffic in IoT, which is inspired by abstract algebra based on experimental research and is aggregated from the multimedia traffics with similar Quality of Experience (QoE) requirements for different users, and improves typical QoE evaluation method for multimedia traffic in IoT.Then a new cross-domain QoE guarantee method based on the iFlow QoE is proposed in this paper to adjust the network resource from the perspective of user perception. The proposed scheme is validated through simulation, which indicates the proposed scheme outperforms the current scheme. Specifically, simulation results show that the proposed scheme achieves an enhancement in QoE performance for the multimedia traffics. Furthermore, it retains the perceived QoE of the real-time application users within high satisfaction levels.**

Index Terms— **Internet of Things, Diffserv networks, Quality of experience, Multimedia traffic**

I. INTRODUCTION

With increasing in personalized service requirements and the number of smart objects and/or devices such as smart phones and smart TVs in Internet of Things (IoT), which can communicate and interact with each other via heterogeneous networks (e.g., Wireless Fidelity (WiFi) Differentiated Services (DiffServe), Long Term Evolution (LTE) and Blue-tooth) [1][2][3][4], multimedia traffics are gaining considerable popularity in IoT[5], which requires very different Quality of Experience (QoE), and could be delivered through the routes with different features to meet their QoE requirements with the lowest costs [6]. Especially in real time IoT applications, multimedia traffic may experience network delay and congestions due to bandwidth constraints and packet loss, which have an adverse impact on the delivered multimedia quality [1]. The challenges to guarantee QoE of multimedia traffic are increasingly prominent in IoT for user. Therefore, Research on Quality of Experience (QoE) in multimedia traffics in IoT has gained attention in recent years [1].

The International Telecommunication Union (ITU-T) has defined QoE as the whole thing of acceptability of the services subjectively perceived by the IoT users. According to the definition of the European Qualinet society, QoE is the degree of being happy or annoying for IoT users of the services. Many research efforts have been devoted to QoE-driven resource allocation. Besides, a high-accurate allocation algorithm is proposed to manage the IoT from experience, and improve the close-to-green solution based on Deep Learning(DL)[7].

The IoT is made up of billions of intelligent objects and/or smart devices connected via the Internet. Its application has

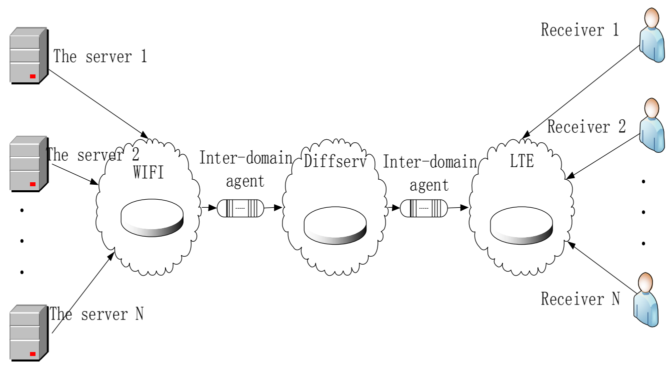

Fig. 1. A typical scenario of multimedia communication in IoT

been extended to transportation, education, medical care, home environment and automation, smart home, smart city and other fields. The IoT objects can collect, process and deliver a variety of information ranging from simple scalar data (e.g. ping message to indicate whether a device is alive) to rich multimedia contents such as audio, image and video[1]. Meanwhile, with the rapid development of mobile communication and Internet technology, a large number of different types of communication networks have emerged, exposing users to a complex and diverse heterogeneous network environment. Generally, multimedia services form IoT need traverse many different types of networks, which have a variety of communication modes and access means. On the other hand, different user has obviously different perceived quality of service for the same traffic since different user has different personalized service requirements. Even if the same

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Zaijian Wang is with The College of Physics and Electronic Information, Anhui Normal University, Wuhu, CO 241000 China. (+8613695673538;e-mail: wangzaijian@ustc.edu).
Chen Chen is with The College of Physics and Electronic Information, Anhui Normal University, Wuhu, CO 241000 China. (e-mail: Alice-Cr@ahnu.edu.cn).
Xinheng Wang is with School of Computing, University of the West of Scotland, Paisley, PA1 2BE, UK (e-mail: xinheng.wang@uws.ac.uk)
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user may be have different perceived quality of service for the same traffic at different time or in different environment. As a result, QoE satisfaction will be a major challenge for IoT user.

As shown in Fig.1, multimedia traffic will tranverse three typical networks(WiFi, DiffServe, and LTE), which provide differented service by different granularity traffic category for multimedia traffics. For example, WiFi guarantees the quality of multimedia services by adopting four Access Categories (AC): AC_VO, AC_VI, AC_BE and AC_BK.. DiffServ developed by the Internet Engineering Task Force (IETF) guarantee the quality of traffics by processing different traffic classes in different ways, according to their requirements guarantee the quality of traffics by processing different traffic classes in different ways, according to their respective DiffServ Code Point (DSCP) values., which is deployed by several commercial ISPs and across the pan-European education and research network GÉANT. However, LTE standardised by 3rd Generation Partnership Project (3GPP) in Release 8 adopts network-initiated bearers to guarantee the quality of traffics based on traffic differentiation and prioritization of data flows, which is an all-IP network and uses new multiple access schemes on the air interface. The users are exposed to a complex and diverse heterogeneous network environment. When networks cannot effectively interconnect with each other, the QoE of users cannot be guaranteed, so that the effectiveness of the network greatly is weakened. Especially, the user's behavior is dynamic, who can use different applications or services in different preferences, which will also make the user experience different.

QoE includes two main aspects [8]: Quality of Service (QoS) and human perception. QoS mechanism is mainly responsible for the business management from the viewpoint of network and provide business diversity, and the artificial part is through the other objective methods to measure, the main features of QoE is depends on the person's emotion, hobbies, etc.The future of the Internet, the overall goal is to make the application of transparent, efficient, flexible use of the available network resources, the goal of our future multimedia network communication is also required to meet the personalized user satisfaction with the needs and expectations.

Although some excellent works have been done on end-to-end QoE provisioning in IoT[6], very little efforts are made on utilizing QoE classification to provide end-to-end QoE provisioning. To the best of our knowledge, only a few existing studies have researched the end-to-end QoE provisioning issues in IoT. Inspired by the concept of graphic isomorphism, it seems feasible to differentiate multimedia traffics by aggregating the multimedia traffics with similar QoE requirements for different users to generate "Isomorphism Flow"(iFlow). This paper mainly focuses on the cross-domain QoE guarantee, and the main contributions are as follows.

1) introduces a new concept of isomorphic flows according to QoE requirements, by which the multimedia traffics are classified to provide differentiated services for users from the perspective of user perception;

2) improves a typical QoE evaluation model to make its evaluation results closer to the real value;

3) proposes a new cross-domain QoE guarantee method based on the iFlow, in which the network resource is allocated according to user's QoE requirements.

The rest of this paper is organized as follow. The related works are described in Section II. The Section III introduces typical QoE features and Isomorphic flow concept. The Section IV describes a new cross-domain QoE guarantee method based on the iFlow. In Section V,the simulation results are given. Finally, Section VI concludes this paper and also provides suggestions for future work.

II. Related Works

Since multimedia traffics play a major role in IoT applications, the research on the quality of experience in the multimedia communication of the IoT has attracted much attention in recent years. In many paper, a large number of models and evaluation methods are provided for QoE calculation and related QoE requirements. This paper mainly focuses on the 4 aspects as follows: 1） QoE guarantee method; 2） QoE evaluation model ; 3） traffic classification ; 4） The foundations basic of isomorphism.

A. QoE guarantee method

For multimedia communications in IoTs, the paper [1] introduces a new concept of Quality of Things (QoT), and proposes a new quality aware IoT architecture based on the QoT for multimedia IoT applications to ensure the quality of multimedia content to be collected, processed and delivered appropriately in such applications. Paper [5] proposes a QoE-driven framework named Smart Media Pricing (SMP) to price the QoE for IoT multimedia services, which is translated to a game theoretical QoE maximization problem. Paper [6] proposes a novel vehicle network architecture in the smart city scenario, in which a joint resource management scheme is proposed to mitigate the network congestion with the joint optimization of caching, networking and computing resources.

Based on the centrality of nodes, the paper [7] proposes a suboptimal dynamic method which is suitable for the IoT with frequent content delivery, and a green resource allocation algorithm based on Deep Reinforcement Learning (DRL) to improve the accuracy of QoE in an adaptive manner. The model proposed in the [7] can capture the network cost and the influencing factors of IoT user service according to the conditions of the IoT, and pay attention to the issues of cache allocation and transmission rate. Under this content-centric IoT, the goal is to allocate cache capacity between content-centric computing nodes and process transmission rates within the total network cost and Mean Opinion Score (MOS) limits for the entire IoT. Paper [9] presents an IoT-based architecture for multi sensorial media delivery to TV users in a home entertainment scenario. Paper [10] formulates a computation offloading game to model the competition between IoT users and allocate the limited processing power of fog nodes efficiently. Each user aims to maximize its own QoE, which reflects its satisfaction of using computing services in terms of the reduction in computation energy and delay. Through numerical studies, it evaluates the users' QoE as well as the equilibrium efficiency. This paper reveals that by utilizing the proposed mechanism, more users benefit from computing services in comparison to an existing offloading mechanism. It further show that the proposed mechanism significantly reduces the computation delay and enables low-latency fog computing services for delay-sensitive IoT applications

For 4G/5G networks, paper [11] thinks that it is essential to improve QoE through clustering. This paper also discusses the potential challenges of implementing clustering schemes to Internet of Things (IoT) systems in 5G networks, and indicates that clustering techniques enhanced with smart network selection solutions could highly benefit the QoS and QoE in IoT. Paper [12] presents a solution for intelligent network in LTE and WiFi integrated network. Considering that the optimization target is network throughput without considering the preference of user QoE in most existing channel allocation methods, paper [13] proposes the joint channel allocation algorithm to improve the satisfaction of more users by combing with the user's QoE preference and the loss of each user's QoE for 5G networks. Paper [14] proposes a 5G QoE system capable of extracting video metadata and stream QoS metrics.

For D2D communication, paper [15] proposed the congestion consciousness D2D support mode of communication, and attempts to establish direct communication between sender and receiver to reduce the pressure of the base station. Paper [16] proposes a collaborative scheme for achieving efficient differentiated QoE scalable video multicast equipment cooperation. For a group of user devices with different preferences in QoE, the heterogeneous experience quality requirements are met through D2D communication. For Machine to Machine (M2M) communication, paper [17] proposes an access Wireless Sensor Network (WSN) gateway to provide access and connectivity for Machine Type Devices (MTD) traffic, and a traffic flow management policy to define the existence of IoT traffic with Human-to-Human traffic over an Evolved Packet System (EPS) network and provide an acceptable level of Network QoS (NQoS) for machine type communication traffic flows, while preserving the QoE of human type communications.

These papers all indicate that there are some unreasonable or waste of resources in the process of network resource scheduling. We need to propose new schemes to make the network more optimized and the user experience quality higher.

B. *QoE evaluation method*

According to different classification standards, the QoE evaluation methods can be divided into different types. Paper [18] gives a comprehensive survey of QoE methods, and summarizes the methods into three categories.

1) subjective evaluation methods: QoE is obtained from subjective test, where human viewers evaluate the quality of tested traffics under a laboratory environment;

2) objective evaluation methods: objective quality models are developed to predict QoE based on objective QoS parameters;

3) data-driven QoE analysis methods: this method adopts measurable QoE metrics, e.g., viewing time, probability of turn, etc.

Subjective evaluation method refers to the evaluation given in a specific and controlled environment according to people's feelings, and the Mean Opinion Score (MOS) of multiple testers is finally obtained as the benchmark for the quality of each sequence. At present, ITU-T has launched corresponding subjective quality assessment standards for different video services [19]. Typical subjective evaluation methods include Double Stimulus Continuous Quality Scale (DSCQS), Double Stimulus Impairment Scale (DSIS) and Single Stimulus Continuous Quality Scale (SSCQE) [20]. Objective evaluation method is mainly to establish the mapping relation between the quality and the quality by using the relevant information of multimedia, so as to make the result as close as possible to the subjective. Considering the dependence on original video, the objective evaluation methods are: Full reference, partial reference, and no-reference video quality assessment [21]. In addition, objective evaluation methods based on input parameter types can be divided into: parameter planning model, packet layer model, bitstream layer model, mixed layer model and media layer model [22]. These models are applicable to different situations. Data-driven QoE analysis method carries out, large-scale measurement studies in various services.

To enhance the satisfaction of QoE, paper [7] proposes QoE models to evaluate the qualities of the IoT concerning both network and users, which could capture the influence factors from network cost and services for IoT users based on IoT conditions. Paper [14] presents a QoE predictive assessment scheme that can be applied to real-world network environments with real-time processing requirements. Paper [23] gives a model of user's QoE:

$$QoE_{QoE} = \alpha e^{-\beta QoS} + \gamma \quad (1)$$

Where α,β and γ are the parameters constraining the quantization of QoE. QoS represents the QoS a user can obtain. It mainly evaluates user QoE based on various network parameters.

Paper [24] studies the influence of odor type on the user's QoE level, and suggests to add olfactory sense to improve user QoE. Paper [25] defines the user satisfaction level of video streaming through the function formula, which utilizes emotions to predict the user's QoE and puts forward to customize the personalized content through the viewer's emotional feedback so as to improve the method of video QoE user experience. Paper [26] chooses the most relevant packet loss rate of QoE evaluation, shows that there is an effective exponential relationship between QoS and QoE, and the exact relationship between QoS and QoE is determined by Weber Fechner Law (WFL). Paper [27] calculates the QoE level of a service class application by a nonlinear monotone increasing function, which is called the association model.Paper [28] and [29] discusse some environmental factors parameters of user QoE modeling.

In our works, user's preferences and tags are very important in real-time communication. Our focus is not all on all network parameters, But the user's preferences for different whether to change the user experience, Whether the scheme we built based on this can meet the requirements of user evaluation, therefore, users' geographical location, gender, network parameters and preferences will be taken into account in our real-time communication software.

C. *Traffic classification*

To meet user's QoE requirements due to personalized service, a lot of networks provided differentiated services by classifying traffics. We have done some preliminary classification method for business work, got some research results of multimedia data [2]. Paper [30] proposes a network mapping scheme based on aggregation flow to address the end-to-end quality of multimedia services in heterogeneous networks, , which avoids loss of information due to mapping between different granularity QoS domains of QoS classes and provides effective network resources according to user QoE. WiFi network provides four Access Categories (AC)（ AC_VO, AC_VI, AC_BE and AC_BK..）and eight user priorities（0~7）for traffics [31]. LTE[32] defines 9 categories for traffics, in which QoS Class Identifier (QCI) is used as identification mark and the range of QCI is 1-9, corresponding to different resource types, priority, delay and packet loss rate. QCI is also divided into Guaranteed Bit Rate (GBR) and non-guaranteed Bit Rate (non- GBR). The former is used for businesses with high real-time requirements, while the latter is used for businesses with low real-time requirements. To address the problem of ensuring user QoE in the HNs of IEEE802.11 ad and LTE-A, a hierarchical HNs admission control strategy based on QoE is proposed in the paper [33]. The proposed policy allocates resources to the horizontal layer according to the priority of the vertical hierarchical access category. The results show that the strategy can significantly improve average QoE for HNs users. WiMAX2(802.16m)[34] defines six scheduling business types for end-to-end QoS business (UGS, ertPS, rtPS, nrtPS, BE) and AGP(Adaptive Granting and Polling service). Because QoS classification is different in different network, it id necessary to redefine traffic classification from the perspective of user perception toprovide end-to end QoE guarantee .

D. *The foundations basic of isomorphism*

Bijective: in mathematics, bijective is a mapping that is not only monojective but also surjective, also called "mapping".

Let's say that f is a mapping from set A to set B. If f(A)=B, that is, any element b in B is an image of some element in A, then f is called the surjection from A to B.If a (1) is not equal to a (2) for any two different elements in A, and their image f is not equal to f, then f is called as A single shot from A to B. When the mapping f is both monojective and surjective, it is called "bijective" (or "one-to-one mapping") from A to B.The function is bijective when and only if each possible image has and only one variable corresponds to it.

Isomorphism: if the homomorphism mapping f is a bijective mapping, then f is called the isomorphism mapping from G to G'. In this case, group Gand G' isomorphism are called. Isomorphism in mathematics said two mathematical object relations, said the two objects on the mathematical structure or rule has certain similarity, to see their relationship on attributes or processing. It refers to the commonness between different images when integrating different image materials into new images.

Graphic isomorphism: this isomorphism is based on the possibility of potential morphological or meaningful intrinsic connections between these figures. When designing isomorphic graph in mathematics, we can start from two aspects. First, we can consider the shape of graph and observe whether there is a common place that can be combined. The second is to think about the meaning of graphics, paying attention to the relevance of the inherent meaning of graphics, so that they are isomorphic.

Our works are inspired by the concept of graphic isomorphism, and try to provide differentiated services from the perspective of user perception by generating **"**Isomorphism Flow"(iFlow), which is aggregated by the multimedia traffics with similar QoE requirements for different users. Based on iFlow, this paper proposes a new cross-domain QoE guarantee method, in which the network resource is allocated according to user's QoE requirements.

III. TYPICAL QOE FEATURES AND ISOMORPHIC FLOW CONCEPT

QoE feature is still at its infancy, and there is still great room for development. The selected QoE features should be a good indicator of user experience or engagement, and easy to track and monitor in real-time [18]. By investigating 50 volunteers, we obtain the distributions of age and gender from the selected volunteers as shown in Fig.2. It is obvious that the users' age and gender will affect their preference for traffics. Furthermore, their further preference proportions for different traffcs are obtained as shown in table 1. Meanwhile, we also investigate hobbies and business categories, which affect user's preference for traffics. This paper mainly focuses on four typical QoE features and provides some meaningful results.

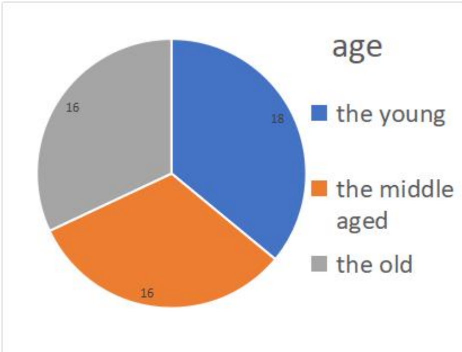

Fig. 2(a). The distributions of age from the volunteers.

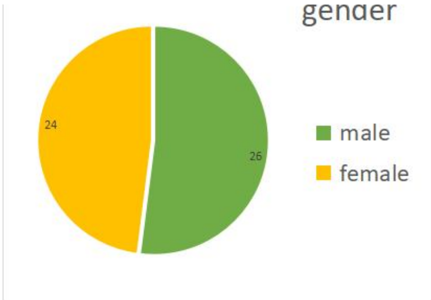

Fig. 2(b). The distributions of gender from the volunteers.

A. Typical QoE Features

The four typical QoE features are as follows.

1) Gender: the gender difference of users is one of the primary factors to be considered in our personalized service. Due to the different physical characteristics of male and female and their different hobbies in most cases, the gender difference of users is ignored.

2) Age group: as far as users are concerned, human loves different things at different ages. Human will change and develop their preferences with growing old, so we also consider them.

TABLE 1 THE EFFECT OF INTEREST ON THE DEGREE OF BUSINESS PREFERENCE

Traffic	**Medical**	**Game**	**Household**	**Message**
Traveling	36%	14%	22%	30%
Reading	18%	22%	36%	22%
Drawing	22%	38%	18%	20%
Music	24%	36%	24%	28%

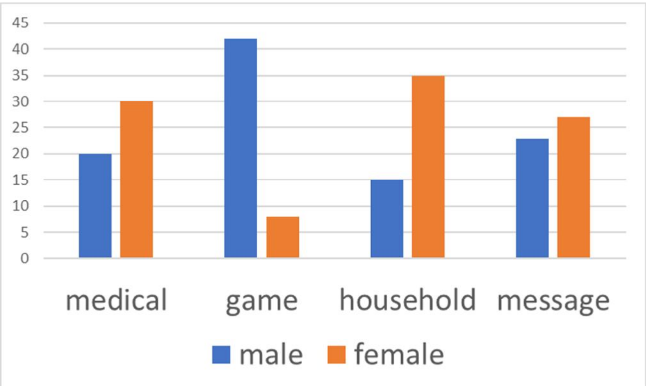

Fig. 3. The percentage of gender preference for four kinds of traffics

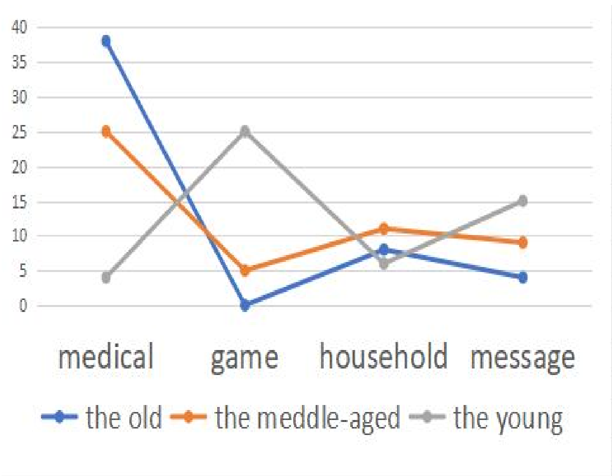

Fig. 4. The effect of age on the degree of traffic preference

3) Hobbies: users' hobbies largely determine their favorite businesses. They are closely related to users' personalities. If we can assign priority of different businesses according to users' interests before evaluation, the evaluation results will be more accurate. Table 1 shows the different traffic preferences caused by different users' hobbies. Table 1 indicates that users with different hobbies have different uses for social software business from the proportion of each user in the traffic preference.

4) Traffic categories: our customers personalized classification purpose is to recommend the accords with the assistance of business, or in the same business to give the user a priority definition, is the scheduling of network resources more reasonable, the kinds of different business correspond to different user's interest, corresponding to different users in the same business, according to different user needs and labels to differentiate their priority, makes the whole group user QoE ascend.

After investigating the selected 50 volunteers for each feature, it shows that the QoE requirements are not completely stochastic. The users with similar age generally have similar preference on traffic categories. Furthermore, the users with similar age and gender generally have more similar preference on traffic categories. For example, women prefer to use video and text services, while men are more likely to enjoy voice services and pictures.

The differences of age for traffic are shown in Fig. 4. Fig. 4 indicates that the frequency of old users enjoying medical traffics are higher than that of young people, however, the young and middle-aged users more like online game and household traffics than old users .

The results of above observation and analysis inspired us that similar QoE requirements may mean similar geometric spatial structure in higher-dimensional QoE space, which is comprised by QoE metrics. In other words, multimedia traffics may be represented by QoE metrics in higher-dimensional QoE space. The multimedia traffics with similar QoE requirements can be aggregated, and provided with differentiated services by similar network operator to guarantee en-to-end QoE for different users.

B. Isomorphic flow concept

According to the concept of graphic isomorphism in abstract algebra, this paper introduces a new concept of “Isomorphism Flow”(iFlow) for multimedia traffic in IoT, which is generated by aggregating the multimedia traffics with similar QoE requirements.

Differenting from typical traffic/QoS classes or aggregation flow, the iFlow is generated according to QoE metrics. The multimedia traffics belonged to the same traffic/QoS classes may be different iFlow categories. Even if the same multimedia traffic may be divided into different iFlow categories when users with different background have different QoE requirements. For the same user, the same multimedia traffic may be divided into different iFlow categories when the users' preference changes with circumstance. Meanwhile, different multimedia traffics may be divided into the same iFlow category when the users' preferences are identical. It is obviously that multimedia traffic is divided into corresponding iFlow from the perspective of QoE, which is different with typical traffic/QoS classes or aggregation flow.

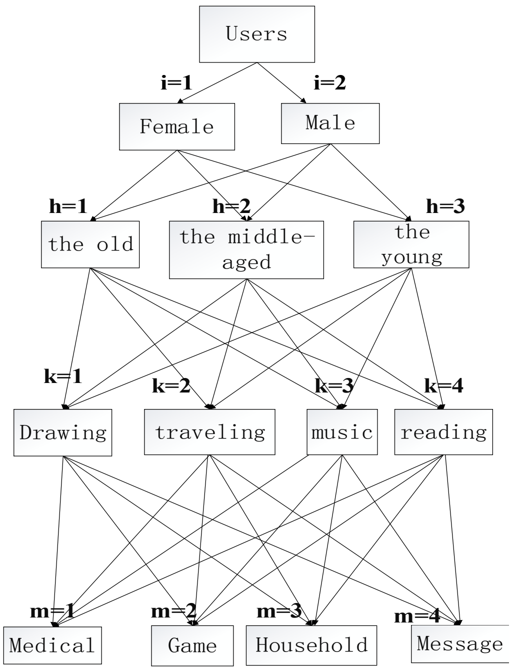

Fig. 5. User characteristics and business association diagrams

TABLE 2 DEFINITIONS OF VARIOUS PARAMETERS

Characteristics	Meaning
Gender	i=1 stands for female，i=2 stands for male
Age	h=1 stands for the old，h=2 stands for the middle age, h=3 stand for the young
Hobby	k=1 stands for drawing，k=2 stands for traveling，k=3 stands for music，k=4 stands for reading
Traffic	m=1 stands for medical，m=2 stands for game，m=3 stands for household，m=4 stands for message

To express easily, a higher-dimensional QoE space is comprised with QoE metrics. In QoE space, the multimedia traffics belonged to the same iFlow categories have similar geometric structures. However, for different users, the same traffics may have different geometric structures with different preference. Each of iFlow categories has sole label. Based on users' QoE, the traffics with same users' QoE and different users have same priority and network operations.Therefore, the iFlow can reflects users' preference and help to utilize efficiently the network resources by classifing the network multimedia traffics into different iFlow categories according to users' QoE. For example, when user A prefers to gameand user B is inclined tochoose household, if users A and B have priorities for their traffics, the game traffic of user A and the household traffic of user B are belonged to the same iFlow category. Otherwise, if users A and B have different priorities for their traffics, the game traffic of user A and the household traffic of user B are belonged to the different iFlow category. In this paper, the traffics selected are divided into four categories (from 1 to 4) to easily explain, for which the value is larger and the priority is higher, The iFlow with higher priority will be assigned with a higher lable value.

As shown in figure 5 and table 2, users can be divided into two genders, respectively, and each of genders can be further divided into three categories in age (the old, ,the middle and the young). Each of age categories has different hobby. Through investigating typical Chinese family, we select four typical activities (drawing, traveling, music and reading) for hobbies. Users selected hobbies have different preference for different four family traffics (medical, game, household and message) .

The priority of traffic is different among users with different tags, the formula of traffic priority is given as follows.

$$D_{\mathrm{j}} = [A_{\mathrm{h}}^{\mathrm{i}}, \ T_{\mathrm{k}}^{\mathrm{m}}] \qquad (2)$$

where D_{j} denotes the j^{th} priority. $A_{\mathrm{h}}^{\mathrm{i}}$ denotes user with i and h, for which the meaning are shown table 2. $T_{\mathrm{k}}^{\mathrm{m}}$ denotes traffic with m and k, for which the meaning are shown table 2.The detailed findings from 50 volunteers is provided in the appendix A, from which the highest priority group D_1 is provided as follows.

$$D_1 = \{ A_1^1, T_1^2; A_1^1, T_3^1; A_1^1, T_3^4; A_1^1, T_4^3; A_2^1, T_1^2; A_2^1, T_2^1; A_2^1, T_3^4; A_2^1, T_4^3; A_3^1, T_1^2; A_3^1, T_1^3; A_3^1, T_2^3; A_3^1, T_3^1; A_1^2, T_1^3, A_1^2 T_4^1; A_1^2, T_4^2; A_1^2, T_4^4; A_2^2, T_1^2; A_2^2, T_3^4; A_2^2, T_4^1; A_2^2, T_4^3; A_3^2, T_1^2; A_3^2, T_1^3; A_3^2, T_3^1; A_3^2, T_3^4 \}$$

From D_1, the same traffics have different priorities for different groups of users. For example, (A_1^1, T_3^1) and (A_3^2, T_3^4)are belonged into the same iFlow with that same priority in proposed method. However, (A_1^1, T_3^1)represents that the older female who likes music preferred medical of home traffics.; (A_3^2, T_3^4) represents that the young men who like music preferred real-time messaging of home traffics.

IV. A NEW CROSS-DOMAIN QOE GUARANTEE METHOD BASED ON THE IFLOW

As shown in Fig. 6, the whole process of the proposed method can be divided into three modules. In module A, multimedia traffics are transmitted. In module B, the multimedia traffics are classified according to QoE characteristics. According to the users' preference from our survey, the corresponding traffics in the queue should be sorted and prioritized. According to the definition of iFlow, ,homogeneous flow scheduling process is started by setting roughly 50 users and 4 priorities for 4 types traffics over heterogeneous networks, Since the users have different preferences, the users are divided into different priorities. The user with higher preference degree has higher priority by providing the queue with higher priority. Then the corresponding mapping is provided according to the order of priority access to the queue in the network.

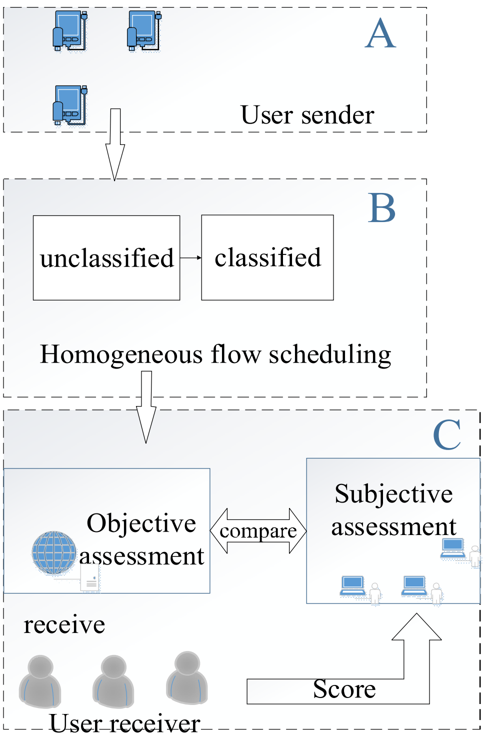

Fig.6. Experience of quality assessment process

The module C,is evaluation module, In which an improved model is utilized to calculate the corresponding user's MOS value. The evaluation includes subjective and objective evaluations, in which the MOS value from objective evaluation model is compared with that from subjective evaluation model. After the comparison, the results is used to verify the accuracy of our improved model.

The proposed method comprises two sections including isomorphic flow scheduling process and QoE evaluation. In isomorphic flow scheduling process sections, the isomorphic flow is introduced. In QoE evaluation section, an improved QoE evaluation process is described. The following figure shows the scenario assessment framework under our architecture.

A. *Isomorphic flow scheduling process*

The detailed homogeneous flow scheduling process is provided in this section. As shown in figure 7, within, each network of HNs has different QoS/traffic classification for different multimedia traffics, $D_i(i=1,2,\cdots,n)$ represents the priority of the corresponding queue i. When the traffics with different priorities are scheduled into different queues in HNs, the queue with higher priority have higher probability to be transmitted. The traffics belonging to the same iFlow category are scheduled into the same queue as shown in figure 7.

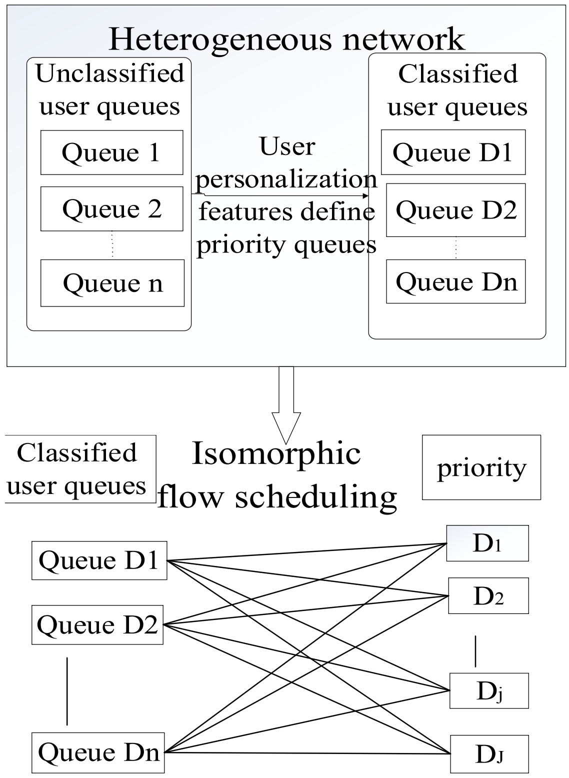

Fig. 7. The effect of age on the degree of business preference

About isomorphic stream classification module, We classify the user tags and the business they use to get the priority of the business that this user is using. The labels used in this article are the characteristics we used to investigate its population..

B. *QoE evaluation*

The typical QoE evaluation model [23] shown in formula (1) considers the influences of various network parameters, however, neglects user preferences so that users' perception can't be reflected. Therefore, this paper tries to improve the model by introducing preference impact factor to increase user interest's weights and enhance the precision of the typical model. M' is selected as the range of preference influencing factors (0,1), for which the value is the smaller, the user's interest is the more consistent with the use of traffic.

This paper assigns different weights and normalized the QoS parameters (resolution, delay and packet loss rate). Q represents the network influence parameter normalized , which is the x-coordinate of the model proposed as follows.

$$Q = \text{resolution}*C1 + \text{delay}*C2 + \text{loss rate}*C3 \quad (Q=0\sim1) \tag{3}$$

where C1 ≈-0.00017, C2 ≈0.01220. C3≈-0.0000001.

The improved model is as follows.

$$QoE = \text{a-MQoE}_{QoS} \tag{4}$$

where QoE_{QoS} denotes the QoE value from formula (1). $\text{M}=\text{M}^{'}+b$, b is the corrected parameter. This paper classified the preferences of the volunteers and identified four preference factors M ', which are defined as M '=0.1, 0.3, 0.6 and 0.9. In order to show more visually, M is calculated by adding an influence factor and a parameter b.

V. EXPERIMENTS

To demonstrate the efficiency of the proposed method, the proposed method is compared with existing schemes in bandwidth utilization performance. Meanwhile the improved QoE evaluation model is analyzed at two cases: considering preference influencing factors or not.

B represents the bandwidth utilization as follows.

TABLE 3
THE VALUES OF DIFFERENT COEFFICIENT

β	α	γ	a	b	M
-2.02	-0.32	0.6	8.65	8.42	M'+ 8.42

$$\text{B}=\text{Y1/Y2}*100\% \tag{5}$$

where Y1 is the bandwidth loss of the use and Y2 is the total bandwidth of the user and. In this paper, the bandwidth utilization is used to calculate the improvement of this proposed scheme compared with the traditional one.

In the simulation environment, 50 volunteers are selected. According to their preferences, the multimedia traffics are divided into medical, game, household, massage.

According to formula (4), the values of different coefficient are obtained as shown in table 3. the value range of $M^{'}$ is the [0, 1].

To verify the effectiveness of the improved QoE evaluation method, the proposed QoE model is evaluated when $M^{'}=0$ and $M^{'}=1$ respectively. $M^{'}=0$ means that the preference influencing factor isn't considered; $M^{'}=1$ means that the preference influencing factor is considered. The results of comparison are shown in Fig.8. Based on formula (4) , table 3 and subjective evaluation, the formulas can be obtained as follows.

$$\begin{cases} QoE = 2.688\text{e}^{-2.02QoS} + 6.3916 & M^{'}=0 \\ QoE = 2.9664\text{e}^{-2.02QoS} + 1.60478 & M^{'}=1 \end{cases} \tag{6}$$

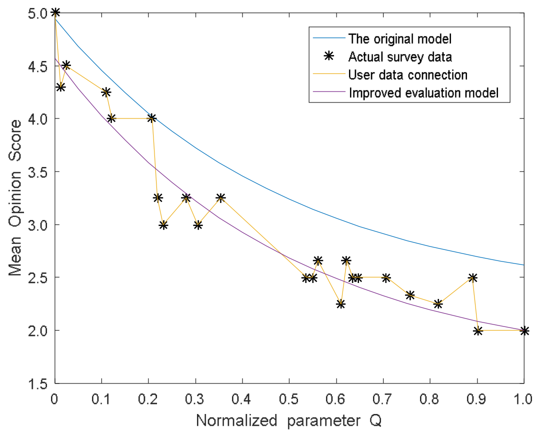

Fig.8. The comparison between the original model and the present model and our research results

After normalizing the network parameters, this paper compares the results of evaluation among three models. To facilitate observation, the average MOS value is utilized in x-coordinate. As shown in Fig.8, it is observed that the results of subjective evaluation are closer to the improved model than that of typical model. The simulation results indicates that the MOS value of typical model is higher than that of subjective evaluation since the typical model neglects users' preferences.

When $M^{'}$ selects 0.1, 0.3, 0.6 and 0.9 respectively, Equation (7) is obtained according to Equation (4) as follows.

$$\begin{cases} QoE = 2.71872\text{e}^{-2.02QoS} + 2.19304 & M^{'}=0.1 \\ QoE = 2.77376\text{e}^{-2.02QoS} + 2.06232 & M^{'}=0.3 \\ QoE = 2.85632\text{e}^{-2.02QoS} + 1.86624 & M^{'}=0.6 \\ QoE = 2.93888\text{e}^{-2.02QoS} + 1.67016 & M^{'}=0.9 \end{cases} \tag{7}$$

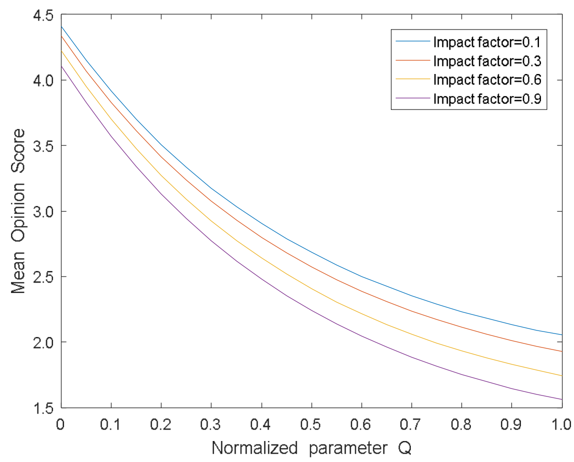

Fig. 9. Shows the curves obtained by the four preference factors of the present model

The computing result of Equation (7) is shown in Fig.9. It indicates that those different traffics have different influence degrees for the same user. The user has higher preference to medical traffic, the MOS value is higher.

To verify the effectiveness of the new cross-domain QoE guarantee method, the proposed QoE guarantee method is compared with Aggregate flow method and mapping table[30] in bandwidth utilization performance. Based on iFlow, the simulation is carried out and the results are shown in Fig.10. Fig. 10 indicates that the broadband utilization ratio of the new cross-domain QoE guarantee method is significantly higher than that of the others.

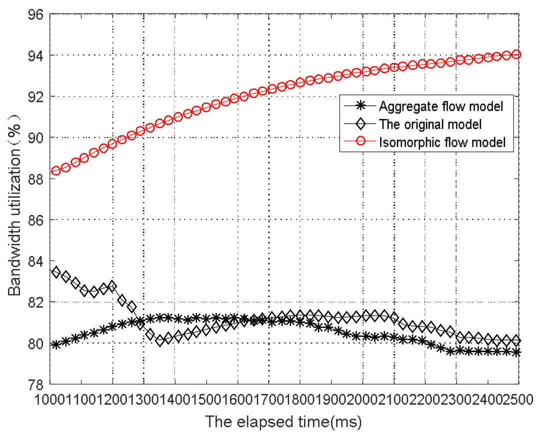

Fig. 10. Bandwidth utilization comparison chart

VI. CONCLUSIONS

In this paper, a new cross-domain QoE guarantee method based on the iFlow is presented to provide user with good perception and acquire high utilization ratio of network resources for multimedia traffic in IoT. After investigating the behavior of multimedia traffic and analyzing typical QoE features of multimedia traffic in IoT, a new concept of Isomorphism for multimedia traffic is introduced. Based on Isomorphism, iFlow is generated by aggregating different traffics with similar QoE requirements. Furthermore, an improved QoE evaluation method is proposed, in which the user interests has the very high weight. The simulation studies are given to demonstrate the efficiency of the proposed method.

REFERENCES

[1] Amulya Karaadi ; Lingfen Sun and Is-Haka Mkwawa "Multimedia Communications in Internet of Things QoT or QoE"2017 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData).2017,Pages:23-29

[2] Zaijian Wang; Yuning Dong; Shiwen Mao; Xinheng Wang, Internet Multimedia Traffic Classification from QoS Perspective Using Semi-supervised Dictionary Learning Models, IEEE/CIC China Communications, 2017.10, 14(10): 202~218, SCIE

[3] Zaijian Wang; Shiwen Mao; Lingyun Yang; Pingping Tang, A Survey of Multimedia Big Data, IEEE/CIC China Communications, 2018, 15(1): 155~176

[4] Elahe Naserian; Xinheng Wang; Keshav Dahal; Zhi Wang; Zaijian Wang, Personalized Location Prediction for Group Travellers from Spatial-Temporal Trajectories, Future Generation Computer Systems, 2018.1, 24(1): 1~15

[5] Wei Wang and Qin Wang， "Price the QoE,Not the Data：SMP-Economic Resource Allocation in Wireless Multimedia Internet of Things" IEEE Communications Magazine，2018，Vol.56. Issue.9，Pages 74-79

[6] Meng Li, Pengbo Si, Yanhua Zhang, "Delay-Tolerant Data Traffic to Software-Defined Vehicular Networks with Mobile Edge Computing in Smart City," IEEE Transactions on Vehicular Technology(Early Access), pp.1-14, 2018

[7] Xiaoming He ; Kun Wang ; Huawei Huang ; Toshiaki Miyazaki ; Yixuan Wang ; Song Guo"Green Resource Allocation based on Deep Reinforcement Learning in Content-Centric IoT"IEEE Transactions on Emerging Topics in Computing 2018 , (Early Access)Pages: 1 – 1

[8] Bo-Wen Chen, , Wen Ji,Feng Jiang, and Seungmin Rho "QoE-Enabled Big Video Streaming for Large-Scale Heterogeneous Clients and Networks in Smart Cities" IEEE Access，Vol.4 2016, :97 - 107.

[9] Lana Jalal , Matteo Anedda , Vlad Popescu , Maurizio Murroni,"QoE Assessment for IoT-Based Multi Sensorial Media Broadcasting" IEEE Transactions on Broadcasting 2018, Vol.64, Issue: 2 Pages: 552 – 560

[10] Hamed Shah-Mansouri , Vincent W. S. Wong"Hierarchical Fog-Cloud Computing for IoT Systems: A Computation Offloading Game"IEEE Internet of Things Journal 2018, Vol.5, Issue: 4 Pages: 3246 – 3257

[11] Lina Xu ; Rem Collier ; Gregory M. P. O'Hare"A Survey of Clustering Techniques in WSNs and Consideration of the Challenges of Applying Such to 5G IoT Scenarios"IEEE Internet of Things Journal 2017 , Vol.4 , Issue: 5Pages: 1229 – 1249

[12] LinaXu，Ning Cao" Network Selection in Hetnets for Advanced IoT Systems: A Demonstration Based on WiFi and LTE " 2017 IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC),2017, Vol. 2 Pages: 301 – 304

[13] Wu D，Wu Q，Xu Y,et al. "QoE-Based Distributed Multichannel Allocation in 5G Heterogeneous Cellular Networks: A Matching-Coalitional Game Solution " [J]. IEEE Access, 2017, 5(99):61-71.

[14] James Nightingale ; Pablo Salva-Garcia ; Jose M. Alcaraz Calero ; Qi Wang .5G-QoE: QoE Modelling for Ultra-HD Video Streaming in 5G Networks[J].IEEE Transactions on Broadcasting 2018, Vol. 64, Issue: 2 Pages: 621 – 634

[15] Wen Sun,and Jiajia Liu, "Congestion-Aware Communication Paradigm for Sustainable Dense Mobile Crowdsensing" IEEE Communications Magazine 2017, Vol.55, Issue: 3 Pages: 62 – 67

[16] Cao Y, Maaref A. Device cooperation-assisted scalable video multicast with heterogeneous QoE guarantees[C]. 2014 IEEE International Symposium on Wireless Communications Systems. Barcelona,Spain, 2014:733-738.

[17] Basim K. J. Al-Shammari ; Nadia Al-Aboody ; Hamed S. Al-Raweshidy"IoT Traffic Management and Integration in the QoS Supported Network" 2018, Vol. 5, Issue: 1 Pages: 352 – 370

[18] Yanjiao Chen, Kaishun Wu, Qian Zhang.From QoS to QoE: A Tutorial on Video Quality Assessment[J]. IEEE Communications Surveys & Tutorials, 2015, 7(2):1126-1165

[19] ITU-T Recommendation P.913. Methods for the subjective assessment of video quality，audio quality and audiovisual quality of Internet video and distribution quality television in any environment.2014

[20] ITU-R Recommendation BT.500-11.Methodology for the subjective assessment of the quality of television pictures.2002

[21] Winkler S，Mohandas P.The evolution of video quality measurement：from PSNR to hybrid metrics[J].IEEE Transactions on Broadcasting，2008,54（3）：660-668..

[22] Takahashi A，Hands D，Barriac V.Standardization activities in the ITU for a QoE assessment of IPYV[J].IEEE Communications Magazine，2008,46（2）：78-84

[23] Paulos Charonyktakis, Maria Plakia, Ioannis Tsamardinos, and Maria Papadopouli. "On User-Centric Modular QoE Prediction for VoIP Based on Machine-Learning Algorithms" IEEE Transactions on Mobile Computing 2016, Vol. 15, Issue: 6 Pages: 1443 – 1456

[24] Niall Murray, Member, IEEE, Brian Lee, Yuansong Qiao, and Gabriel Miro-Muntean, Member, IEEE, " The Impact of Scent Type on Olfaction-Enhanced Multimedia Quality of Experience， " IEEE Transactions on Systems, Man, and Cybernetics: Systems, 2017, Vol. 47, Issue: 9 Pages: 2503 – 2515

[25] Xiaoming Tao, Linhao Dong, Yang Li, Jizhe Zhou, Ning Ge, and Jianhua Lu, "Real-Time Personalized Content Catering via Viewer Sentiment Feedback: A QoE Perspective" IEEE Network 2015, Vol. 29, Issue: 6 Pages: 14 – 19

[26] Youssef Y B, Afif M, Tabbane S. Novel AHP-based QoE factors' selection approach[C]. 2016 IEEE/ACS 13th International Conference of

Computer Systems and Applications (AICCSA). Agadir, Morocco, 2017:1-6.
[27] H. J. Kim et al., "The QoE evaluation method through the QoS–QoE correlation model," in Proc. IEEE 4th Int. Conf. Netw. Comput. Adv. Inf. Manage., 2008, pp. 719–725.
[28] Michael James Scott, Sharath Chandra Guntuku, Weisi Lin, Fellow, and Gheorghita Ghinea, "Do Personality and Culture Influence Perceived Video Quality and Enjoyment?" IEEE Transactions on Multimedia 2016, Vol. 18, Issue: 9 Pages: 1796 – 1807
[29] Karan Mitra, Arkady Zaslavsky, and Christer Åhlund , " Context-Aware QoE Modelling, Measurement,and Prediction in Mobile Computing Systems" IEEE Transactions on Mobile Computing 2015, Vol.14, Issue: 5 Pages: 920 – 936
[30] Wang Z J, Dong Y N, Wang X. A Dynamic Service Class Mapping Scheme for Different QoS Domains Using Flow Aggregation[J]. IEEE Systems Journal, 2015, 9(4):1299-1310.
[31] Belhocine Amin, and Fedoua Didi. QoS : from WIFI to UMTS[C]. 2017 Third International Conference on Multimedia Big Data (BigMM)
[32] Ohta Y, Michiharu N, Aikawa S, et al. Link layer structure for LTE-WLAN aggregation in LTE-Advanced and 5G network[C]. 2015 IEEE Conference on Standards for Communications and Networking (CSCN). Tokyo, Japan. 2016:83-88.
[33] Zhang Z, Zhang Y. Layered admission control algorithms with QoE in heterogeneous network[J]. Ad Hoc Networks, 2016, 58：179-190.
[34] Mehdi Alasti, Behnam Neekzad, Jie Hui, et al.. Quality of service in WiMAX and LTE networks[J]. IEEE Communications Magazine, 2010, 48(5): 104-111.

Wang Zai-jian received his BEng degree from Anhui Polytechnic University, Wu'hu, Chian, in 2002 , MSc degree in circuits and systems from University of Science and Technology of China, He'fei, China, in 2005, and his PhD degree in signal and information processing from Nanjing University of Posts and Telecommunications, China, in 2015.. Currently, he is an associate professor at College of Physics and Electronic Information, An'hui Normal University, Wuhu, China. His current research interests focus on end-to-end QoS provisioning and wired/wireless multimedia streaming.

Chen Chen received her BEng degree from Wanjiang College of An'hui University, Wu'hu, Chian, in 2017. She is now pursuing a MSc degree at An'hui Normal University, Wuhu, China. Her current research interests focus on end-to-end QoS provisioning and wired/wireless multimedia streaming

Xinheng Wang received his BEng and MSc degrees in electrical engineering from Xi'an Jiaotong University, China in 1991 and 1994, respectively, and his PhD degree in electronics and computing engineering from Brunel University, UK, in 2002. He is currently with School of Computing, University of the West of Scotland with research interests in wireless networking, Internet of Things, systems condition monitoring, and wireless healthcare.

APPENDIX A priority of various types of users

T_k^m \ A_h^i	A_1^1	A_2^1	A_3^1	A_1^2	A_2^2	A_3^2
T_1^1	3	4	2	4	2	2
T_1^2	1	1	1	2	1	1
T_1^3	3	4	1	1	4	1
T_1^4	3	2	3	3	4	3
T_2^1	4	1	2	3	3	4
T_2^2	4	2	3	4	2	4
T_2^3	2	2	1	3	2	2
T_2^4	4	3	4	4	2	4
T_3^1	1	3	1	2	4	1
T_3^2	2	3	2	3	4	2
T_3^3	4	3	3	4	3	3
T_3^4	1	1	3	2	1	1
T_4^1	2	2	3	1	1	3
T_4^2	3	4	4	1	3	3
T_4^3	1	1	2	2	1	4
T_4^4	2	4	2	1	3	2